Computer Aided Design of Semi-submersible for Deepwater Operations

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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Approved by,

____
(Assoc. Prof. Dr. Fakhruldin B M Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

RUZANNA BINTI ABU BAKAR

ABSTRACT

In PETRONAS, there is no known design library of offshore floaters thus extensive iterative process is typically being engaged for concept design and selection work. Determination of specific parameters with respect to scaled model testing and calibration is not always straightforward, and involves cross referencing between numerical analysis and experimental testing. Hence, the objectives of the project are to develop semi-submersible's hull section to eliminate some of the iteration in concept design and selection work by initiating a semi-submersible computer aided design (CAD) model library for future design selection work and to evaluate the stability of three different values of waterplane area of column of a semi-submersible CAD model at operating condition at the same water depth. The scope of the study is to focus on developing the hull section of a four-column ring pontoon semi-submersible production platform model using CATIA V5R12, the chosen parameter that will be varied is the waterplane area of the column under fixed design specifications and the semi-submersible's stability will be analyze by vertical center of gravity and draft. The design library was achieved through literature review, calculation, part design and assembly design for CAD model development, application of parameters and formula function and analysis and data generation. The expected results would be three sets of semi-submersible's hull CAD model that differ in waterplane area of column with automated selected parameters computation and an analysis on the relation of the waterplane area of column with draft and vertical center of gravity of each model. As a conclusion, the three CAD models of four-column ring pontoon semi-submersible's hull and the analysis are the initiator for the offshore floaters design library which eliminates some of the iteration in conceptual design stage for future design selection work and the increment of waterplane area of column increases vertical center of gravity and reduces draft. Both conditions increased the probability of the semi-submersible to be flooded.

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CHAPTER 1

INTRODUCTION

A lot of shallow water fields have been developed and still producing. Higher demand for hydrocarbon forced us to explore the deepwater fields. Fixed platforms are not suitable for deepwater operations from technical and economic point of views. Therefore, offshore floaters are used to cater for deepwater fields such as semi-submersibles. The fields that needed to be developed and reservoir that will be explored are at different locations thus having different contents of hydrocarbon, different contaminants and different situation to deal with. Engineers would have to study and choose the most suitable semi-submersible design and parameters for the respective field and reservoir.

1.1 Problem Statement

Concept design and selection, which is part of the Front End Engineering Design (FEED), is a critical stage in the design of offshore floaters. Such an exercise is based on a structured approach to meet specific requirement or criterion. Extensive iterative process is typically being engaged in such an exercise due to unavailability of design library of offshore floaters in PETRONAS. In addition, determination of specific parameters with respect to scaled model testing and calibration is not always straightforward, and involves cross referencing between numerical analysis and experimental testing.

1.2 Objective

The objectives of this project are;

1. To develop a CAD model of a semi-submersible's hull section to eliminate some of the iteration in concept design and selection by initiating a semi-submersible CAD model library for future design selection work

2. To evaluate the stability of three different values of waterplane area of column of a semi-submersible CAD model at operating condition at the same water depth

1.3 Scope of the Study

In this project, the focus is on

1. Developing the hull section of a four-column ring pontoon semi-submersible production platform model using CATIA V5R12.

   CATIA V5 is chosen because it represents the modern CAD system available regarding programming concepts and data structures [1].

2. The chosen parameter that will be varied is the waterplane area of the column under fixed design specifications.

The design specifications for this study are [2];

- Water depth = 5500ft (1676.4m)
- Location = Offshore Malaysia, South China Sea
- Topsides weight = 40 256 kips (194.859 MN)
- Topsides dimensions = 220 x 220 x 36 ft (67.056 x 67.056 x 10.973m)
- And all are at operating condition only

3. The stability will be analyzed by vertical center of gravity and draft values.

It will be a quick stability analysis for the semi-submersible's hull section CAD model.

CHAPTER 2

LITERATURE REVIEW

2.1 Computer Aided Design (CAD)

CAD is a computer technology used to design objects. It provides an electronic drafting board for 2D drawings and 3D wireframes, surface and solid models. Currently, there are a few analysis can be done to the solid model such as kinematic, stress and thermal. One of the benefits that can be gained by using CAD is to design by solid modeling to create a digital geometric database which can be transferred downstream to permit engineering analysis and simulation, thus decrease the cost of testing prototypes [3].

CAD systems build the backbone of modern product development processes by offering the most simple and natural way of representing complex mechanical structures that are heavily constrained through a variety of functional, aesthetic and manufacturing demands [4].

Adjami,M and Shafieefar,M [4] stated that the optimization process was applied to the hydrodynamics shape optimization of semi-submersibles, the objective function assess the seakeeping performance of different designs. The optimization practice in this work is a multistage process involving methods from three different fields of knowledge:

- CAD for automated shape generation
- Computational fluid dynamics (CFD) for analysis of wave-body interaction
- MATLAB for probabilistic theory for assessment of seakeeping qualities in irregular seas

The model optimization process is illustrated as in Figure 1. The user selects the objective function, provides the parameters *p*, and selects the start vector of free variables *x* by using this set of data, the hydrodynamic shape optimization starts by creating and discretizing the initial design. The shape parameters are saved for the subsequent hydrodynamic analysis. Before evaluating the wave-body interaction which is time consuming, the design is checked against a set of constraints.

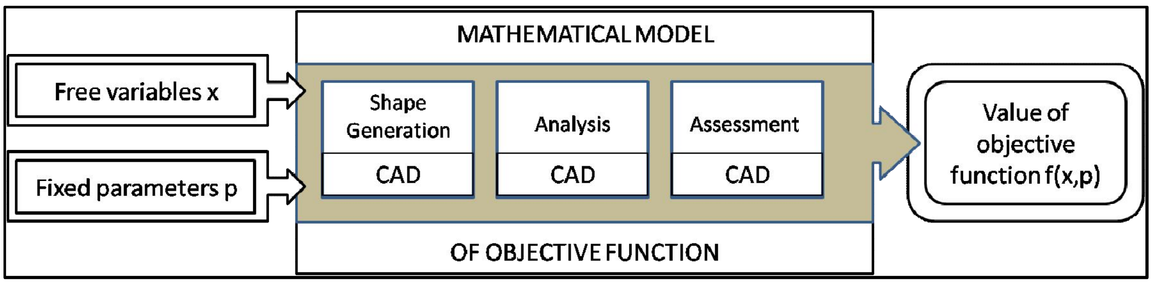

Figure 1: Semi-submersible Based Floating Production System [4]

Computer Aided Design (CAD) system is commonly used in designing. Nowadays in CAD system, the main focus of interest lies in the knowledge application that would allow further improvement in designing process and designing object [5]. Therefore, one of the ways to reduce time consumption on concept design and selection work is by having a CAD model depository for offshore floaters.

2.2 Deepwater Operation

Deepwater is the most attractive and promising upstream oil and natural gas investment areas. However, deepwater developments are commonly categorized by being high profile, costly and technically and technologically challenging. Deepwater is defined when the water depth is more than 1000ft (305m) [6]. The Malaysian Deepwater Production Sharing Contracts (PSC) terminology for deepwater is 200m to 1000m. More than 1000m is called as ultra-deepwater [7]. RIGZONE defines midwater floaters as semisubmersibles and drillships capable of operating in water depths less than 4000ft (1219.2m), deepwater as semi-submersibles and drillships with water depths of 4000ft (1219.2m) to 6999ft (2133.295m) and ultra-deepwater as those units with a water depth capability of 7000ft (2133.6m) or more [8].

There is a shift from shallow water to deepwater for future field developments. Conditions create certain characteristics different from conventional offshore development/operations, including high reservoir pressures, low sea-bed temperatures, large variations in water depth range, flow assurance challenges, geo-hazard issue like gas hydrates and challenge of rough metocean conditions. Thus, conventional offshore solutions, including fixed platform, could not be applied effectively at greater water depths [9].

Deepwater fields are one of the most promising areas of exploration for oil and gas industry. Potential reserves beneath the five primary deepwater basins exceed 100 billion bbl of oil. Industry experts estimate that more than 2500 wells would have to be drilled during the next three decades to access the hydrocarbons [10].

Deepwater prospects are becoming an increasingly important element of the Exploration and Production (E&P) programs for most major oil and gas companies. A forecast predicted approximately 200 deepwater and another 20 ultra-deep (over 5,000ft or 1524m water depth) wells will be drilled in the Gulf of Mexico during 2002, and deepwater E&P expenditures are expected to continue to increase for the foreseeable future [10].

2.3 Floating Offshore Structures

Oil and gas companies will look anywhere to meet the energy demand and the outcomes sometimes lead them to the most inhospitable places. These places have gone beyond practical fixed platform limits therefore; concepts devised by the drilling engineers were adopted. Floating offshore structures like semi-submersibles and drillships emerge and provide viable options in deepwater.

The floaters come in many sizes and shapes. Some provide more functions than others but they have four common elements [11]:

- Hull- the steel enclosure that provides water displacement. The hulls come in ship shapes, pontoons and caissons, or a large tubular structure called a spar.
- Topsides- the deck which have all the production equipment used to treat the incoming well streams. Pumps and compressors needed to transfer oil and gas to next destinations. Normally, topsides include living accommodations for the crew. In most cases, the export lines are connected to the deck.
- Mooring-the connection to the seabed that keeps the floaters in place. Some combine steel wire or synthetic rope with chain and some use steel tendons. In some cases, a huge footprint is installed on the seabed floor.
- Risers- steel tubes that rise from the sea floor to the hull. A riser transports the well production from the sea floor up to the deck.

There are two categories of floating offshore structures, the neutrally buoyant structures and positively buoyant structures.

- Neutrally buoyant structures are semi-submersibles, spars, Mobile Offshore Drilling Unit (MODU), Floating Production System (FPS), Ship-shaped hulls and drillships. They are dynamically unrestrained and allowed to have six degrees of freedom (heave, surge, sway, pitch, roll and yaw).
- Positively buoyant structures are Tension Leg Platform (TLP) and Tethered Buoyant Tower (TBT) or Buoyant Leg Structure (BLS). They are tethered to the seabed and are heave-restrained.

The significant difference between a TLP and a semi-submersible are listed in Table 1 as follows.

Table 1: Difference between TLP and Semisubmersible

TLP	Semi-submersible
Vertical movement is restricted by the tension leg	Movement to all directions are permitted by the mooring system

Table 2 lists the semi-submersible’s functional advantages over the spar [12].

Table 2: Semi-submersible’s Advantages over Spar

Spar	Semi-submersible
Installed by horizontally towing and up-righting at the installation site. A heavy lift vessel must be mobilized to install the topsides using single or multiple module lifts and hook-up and commissioning is completed at sea	Its topside modules can be installed and commissioned at the quayside which offers a large cost saving
Has a number of stacked decks because of its single column form	Has a large open deck area which has a number if operational advantages
Its draft ranged from 500-600ft (152.4-182.88m) which restricts the depths to be towed	Can be vertically wet towed in shallow water

For both categories, the sizing of floating structures is dominated by considerations of buoyancy and stability. Topside weight is important. Semi-submersible and ship-shaped hulls rely on waterplane area for stability. The centre of gravity is typically above the centre of buoyancy. The spar platform is designed so that its centre of gravity is lower than its centre of buoyancy, hence it is intrinsically stable. Positively buoyant structures depend on a combination of waterplane area and tether stiffness to achieve stability [6].

2.3.1 Semi-submersible

Semi-submersibles are multi-legged floating structures with a large deck. These legs are interconnected at the bottom underwater with horizontal buoyant members called pontoons. The early semi-submersibles resemble the ship form with twin pontoons having a bow and a stern. It was considered desirable for relocating the unit from drilling one well to another.

Early semi-submersibles also included diagonal cross bracing to resist the loads induced by waves.

The introduction of heavy transport vessel that permit dry tow of MODU, the need for much larger units to operate in deepwater and the need to have permanently stationed units to produce oil and gas resulted in further development of semi-submersible concept. The next generation semi-submersibles emerge to be a square with four columns and the box or cylinder shaped pontoons connecting the columns. The box-shaped pontoons are often streamlined eliminating sharp corners for better station-keeping. Diagonal bracing is often eliminated to simplify construction [6].

For different water depth, different technologies have been implemented for deepwater developments. There is different type of deepwater development concepts such as dry tree, wet tree and hybrid development. A semi-submersible is categorized under the wet tree development concept [9].

According to Mather [13], a semi-submersible is a semi floating structure that represents the ideal choice of vessel for accurate positioning and good stability. The equipment installed on the main deck and the configurations of the structure will differentiate among the four roles a semi-submersible play as stated below;

a. Heavy lift

It is used for the installation of offshore platforms. The lifting capacity ranges from 2000 to 7000 tonnes. A modern vessel which has tandem cranes is capable of lifting up to 14000 tonnes.

b. Accommodation

Some of the older, smaller heavy lift semi-submersibles are now used to provide extra accommodation and storage space. The semi-submersibles are joined to fixed structures for months at a time to accommodate up to 800 beds for the personnel.

c. Drilling exploration vessel

There are a few drilling operation vessels available but a semi-submersible vessel has no restrictions in terms of water depth. An example, it can be used at a 2250m water depth at a field in the Gulf of Mexico.

The combination of satellite positioning, stability and an abundance of deck space for the storage of drill pipe and well test equipment make the semi-submersible the first choice of vessel for deepwater exploration projects.

d. Pipelay barge

A pipelay barge can install nearly 10 000 km of subsea pipeline in the North Sea during the past 25 years. A modern vessel can lay pipeline between 2 and 4 km a day.

From Wikipedia, semi-submersibles were first developed in offshore drilling. The first semi-submersible is Blue Water Rig No. 1, converted from a four column submersible drilling rig in 1961 by accident. The motions were very small so Blue Water Drilling Company and Shell jointly decided to operate it in floating mode. Since then, a lot of semi-submersibles have been designed [14].

The design of semi-submersibles depends on these principle considerations which are generic to floater concepts [6]:

- Weights and centre of gravity
- Hydrostatics, tank capacities
- Intact and damaged stability
- Wind forces (stability and mooring loads)
- Current forces (mooring loads)
- Ballast system performance
- Motions (seakeeping, drift and low frequency mooring loads)
- Global strength
- Fatigue

Automated optimization is a valuable tool in the design process however, industry does not exercise this option regularly. In the past this may have been justified by ample restrictions on the geometries handled, lack of computing power and unreliable analysis tools. However, a number of research works on automated optimization of offshore structures have been reported.

Adjami and Shafieefar [4] described a fully automated numerical procedure which achieves an optimum adjustment of the shapes of floating systems to environmental conditions. Automated hull optimization relies on the availability of a variety of software tools performing hydrodynamic analysis, assessment of motion behavior; parameters controlled shape generation and variation as well as genetic algorithms controlling the optimization process.

Typical terminologies associated to a semi-submersible are shown in Figure 2 below.

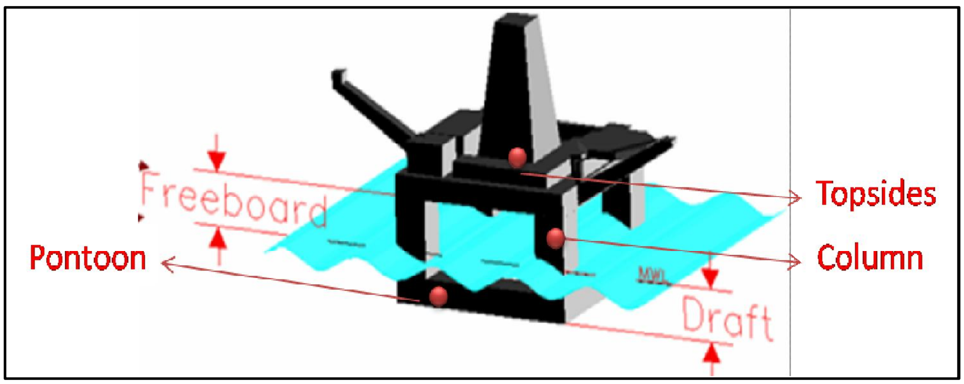

Figure 2: Descriptions of a semi-submersible [2]

2.3.2 General Arrangement and Hull Design

There are a few typical arrangements for a semi-submersible such as the four-column semi-submersible, six-column semi-submersible and eight-column semi-submersible. The arrangement and hull design of one concept depends on the weight, conditions and function of the semi-submersible.

The weights and dimension of the platform topsides required for production and drilling and a location in South China Sea at a water depth of 5500ft (1676.4m) are given. A highly iterative process of altering the key dimensions of a four-column ring pontoon was conducted in order to meet applicable regulations and client requests while minimizing costs and satisfying the chosen competencies. Therefore, the final hull design was a square ring pontoon with outer lengths of 270ft (82.296m), a height of 40ft (12.192m) and a width of 55ft (16.764m). The ring pontoon is topped with four square columns with a length of 50ft (15.24m) to a side and height of 80ft (24.384m). A square topside deck is supported by the four columns with the corners of the topside deck placed at the geographical centers of column tops [2].

The semi-submersible production unit is located in the Gulf of Mexico in a water depth of 5500ft (1676.4m). The vessel will comply with American Petroleum Institute (API) Standards and American Bureau of Shipping (ABS) Rules. Two design options are considered in the report. The selected design utilizes four columns with square cross sections [15].

2.3.3 Weight, Buoyancy and Stability

Buoyancy is modeled as a point force at the geometric center of the submerged portion of the column, each pontoon in the ring and node with a magnitude equal to the weight of displaced water [2].

Buoyancy calculations for the operating case, the total volume of the pontoons is subtracted from the volume of water displaced, resulting in the volume of water that the column displace. This volume is divided by the total cross sectional area off all four columns, which results in the height of the columns that are submerged; this height is added to the height of pontoons in order to obtain the draft of the vessel [15].

On stability, for quick analysis the gravity to metacenter (GM) was used to determine right away if the proposed design dimensions would result in a stable hull or not. This stability analysis was only valid for small angles of list, so StabCad was used for the large angle stability analysis [2].

2.4 FEED

From Petroleum Management Unit Intranet Website, front-end engineering design is a series of design optimization to refine the selected design concept. Optimizations will lead to finalizing the production scenario, tie-in/commingling scenario, energy and material requirement, utility and structure material requirement etc.

FEED is a study used to analyze the various technical options for new developments with the objective to define the facilities required [16].

The traditional approach to front-end engineering is to separate conceptual design from basic engineering activities, and to execute various tasks sequentially.
Conceptual design is primarily performed by process engineers, who generally work with a variety of stand-alone software tools and applications, such process simulation programs, heat exchanger design programs, and equipment sizing and data sheets, as they sketch process flow diagrams (PFDs) and identify critical control requirements on preliminary piping and instrumentation diagrams (P&IDs).

All of these activities are typically accomplished using discrete workflows with little or no reuse of data. Each specialist communicates the data he or she is responsible for in the form of sketches, files, and reports, and all of these documents are then collectively passed on to the basic engineering phase [17].

Around 80% of the overall project costs for an industrial plant project are defined at a very early planning stage, referred to as the front-end engineering and design (FEED) phase. The decisions taken during this project phase significantly influence the subsequent layout tasks and are crucial for the practical suitability, performance and cost-effectiveness of a plant or component.

The FEED phase is divided into three stages:

- Preliminary investment decision by an operator or investor for the construction of a plant
- Bid preparation by an Engineering, Procurement & Commissioning (EPC) service provider
- Early stage of basic engineering following award of contract

The major element of this phase is a cost calculation (±10%) determined by a provisional layout of all delivery items. This constitutes the basis for the binding cost estimate by the EPC service provider and serves as an input for basic engineering [18].

CHAPTER 3

METHODOLOGY

3.1 Methodology

Figure 3 below shows the methods to conduct the project.

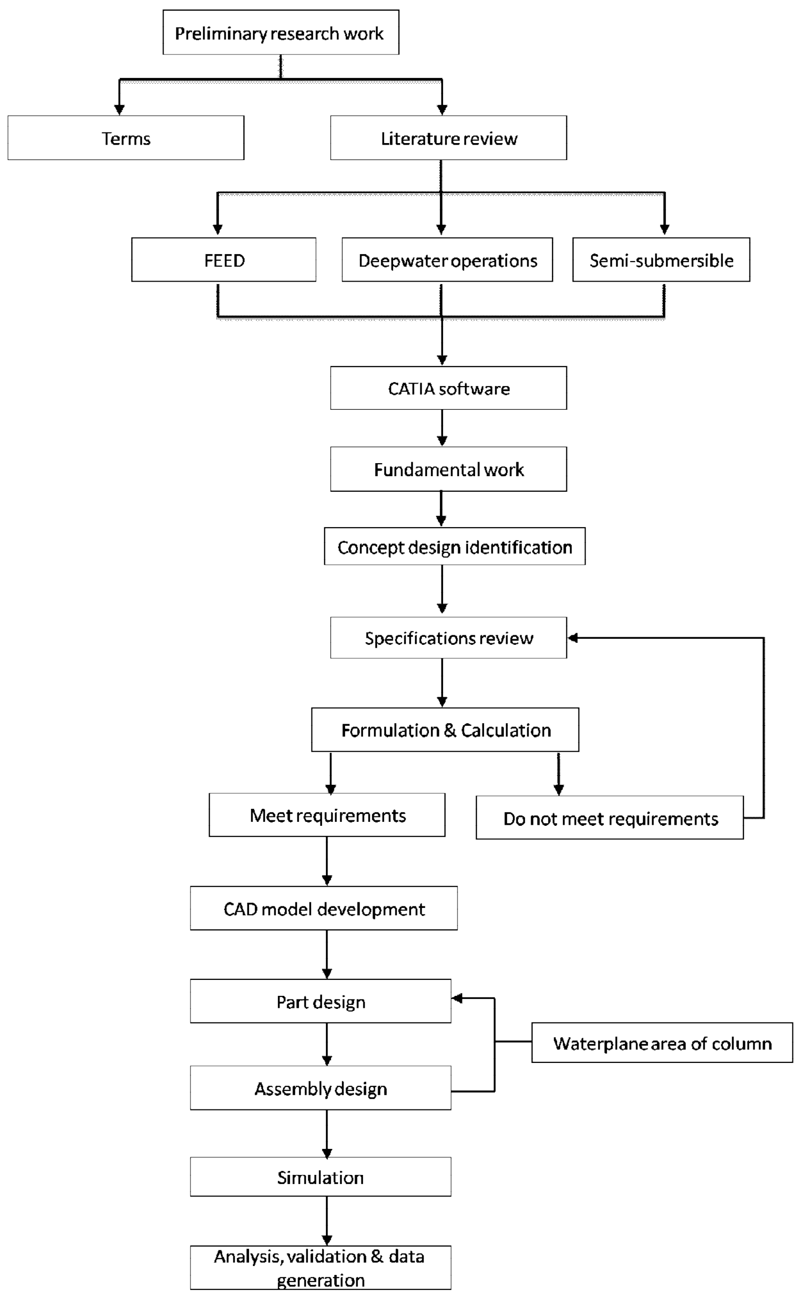

Figure 3: Methodology

3.2 Semi-submersible's Scope

The focus of the project is on the hull section of a semi-submersible. The simple parametric model need only represent the pontoons and columns as prismatic sections [6]. The semi-submersible typically will be tested under three conditions, tow out or loading, operating and survival conditions but this study is conducted at operating condition only.

There are two important points in sizing a semi-submersible, to stably support a payload above the highest waves and to minimally respond to waves. Number, size and spacing of column and height of the topsides play an important role in stabilizing the payload above the highest waves. To minimally respond to waves, the size, shape and submergence of the pontoon relative to the column waterplane area and the spacing of the pontoons and columns are the key factors to look into.

For first estimation, the weights and center of gravity are needed to proceed with a design. This estimate should be continuously refined throughout the designing process. Particular attention should be given to the effective vertical centers of gravity of all items. If the vertical center of gravity of the semi-submersible is known, then the initial stability is known [6].

Therefore, for this study the model is created to stably support a payload and below is the constraints for the semi-submersible in order for it to stay firmly at its position. If the model's dimensions go beyond that, the semi-submersible will flooded [2].

- Minimum value of 72.94ft (22.232m) for VCG
- Maximum value of 85ft (25.908m) for draft

3.3 Formula and Calculation

Stability is the tendency to return to a previous condition when perturbed. If a semi-submersible rolls or pitches, the center of buoyancy shifts. This will determine whether the semi-submersible is stable or otherwise. For this project, the scope is to focus on evaluating stability therefore; two parameters are chosen for the quick analysis. The formulas to find the parameters will be included in the parameters and formula function.

3.3.1 Draft

Draft is the height from the bottom of the pontoon to the waterline level. Draft can be calculated from the Buoyancy formula.

Archimedes principle states that the buoyancy of an object is equal to the weight of displaced fluid.

$$Buoyancy = Displaced\ Fluid\ Weight$$

In order to change the water plane area of column, this rule must be fulfilled. Thus, the first formula is [19]:

$$\begin{aligned} Buoyancy = {} & [(4 \times waterplane\ area\ of\ column \times draft) \\ & + (4 \times cross\ sectional\ area\ of\ pontoon \times length\ of\ pontoon)] \\ & \times seawater\ density \end{aligned}$$

Buoyancy value will be calculated by using dimensions referred to the chosen literature. Next, the buoyancy value is held constant and new drafts are calculated when waterplane area of column is varied.

3.3.2 Vertical Center of Gravity

Vertical center of gravity is found using the centroid formula [20]. Therefore, the second formula used is as below;

Centroid: $(\bar{x}, \bar{y})$

$\bar{y}$ = Vertical Center of Gravity

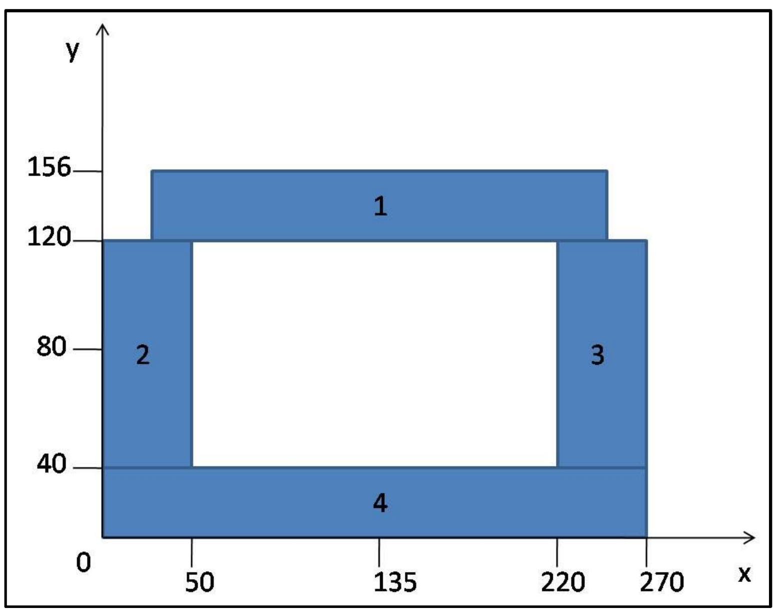

Figure 4: Centroid Calculation Diagram

Based on the diagram above, the formula are;

$$\bar{x} = \frac{x_1 * A_1 + x_2 * A_2 + x_3 * A_3 + x_4 * A_4}{A_1 + A_2 + A_3 + A_4}$$

$$\bar{y} = \frac{y_1 * A_1 + y_2 * A_2 + y_3 * A_3 + y_4 * A_4}{A_1 + A_2 + A_3 + A_4}$$

3.4 CAD Model Development

Figure 1 shows the three parts that will be designed using Part Design sub-module in CATIA V5R12.

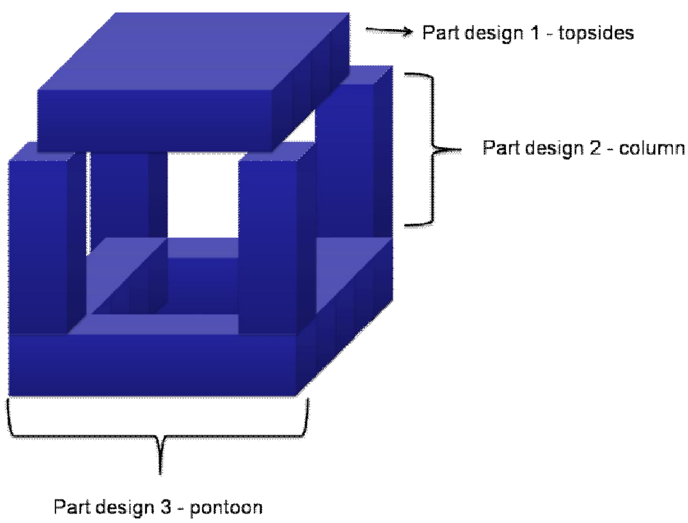

Figure 5: Part Design

The assumption made here is to take part design 1, the topside as solid cuboids with weight representing the real topside and the weight is distributed equally at all direction. Sketcher is used to get the basic rectangular shape of 220ft x 36ft (67.056m x 10.973m) and pad icon was implemented with thickness of 220ft (67.056m).

Column and pontoon both has ballast tank inside them. For this project, the ballast tank is assumed to be the part itself. Therefore, column and pontoon are drawn with empty spaces inside. For column, it is drawn as solid cuboids and shell icon was implemented with 2in (50.8mm) wall thickness.

Part design 3 was started with solid cuboids. Then a 160ft x 160ft (48.768m x 48.768m) square was pocketed in the middle of the solid cuboids. Shell icon was also used with 2in (50.8mm) wall thickness.

3.5 Parameters and Formula Function

In CATIA V5R12, there are a lot of modules available. The modules are Infrastructure, Mechanical Design, Shape, Analysis & Simulation, AEC Plant, NC Manufacturing, Digital Mockup, Equipment & Systems, Digital Process for Manufacturing, Ergonomics Design & Analysis and Knowledgeware.

Under each module, there are a lot of sub-modules. The sub-modules that are used for this project are Part Design and Assembly Design (Mechanical Design module) and Generative Shape Design (Shape module).

An additional part to compute parameters automatically is added to the design library. The additional part is the parameters and formula function in Generative Shape Design is used to insert formula and correlate the formula to the developed CAD model. Appendix A shows the steps in developing the formula function. By doing this, when dimensions are changed to accommodate the respective project requirements, the function can compute automatically a few parameters such as vertical center of gravity (VCG) and draft. These parameters are useful for quick stability analysis on the input dimensions.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

- Three sets of the hull section of semi-submersible CAD model that differ in waterplane area of column with automated selected parameters computation
- An analysis on the relation of the waterplane area of column with draft and VCG and draft with VCG of each semi-submersible's hull model

Three CAD models of a semi-submersible's hull section were created. One was developed according to the dimensions from the chosen literature [2]. The outcome is as shown below;

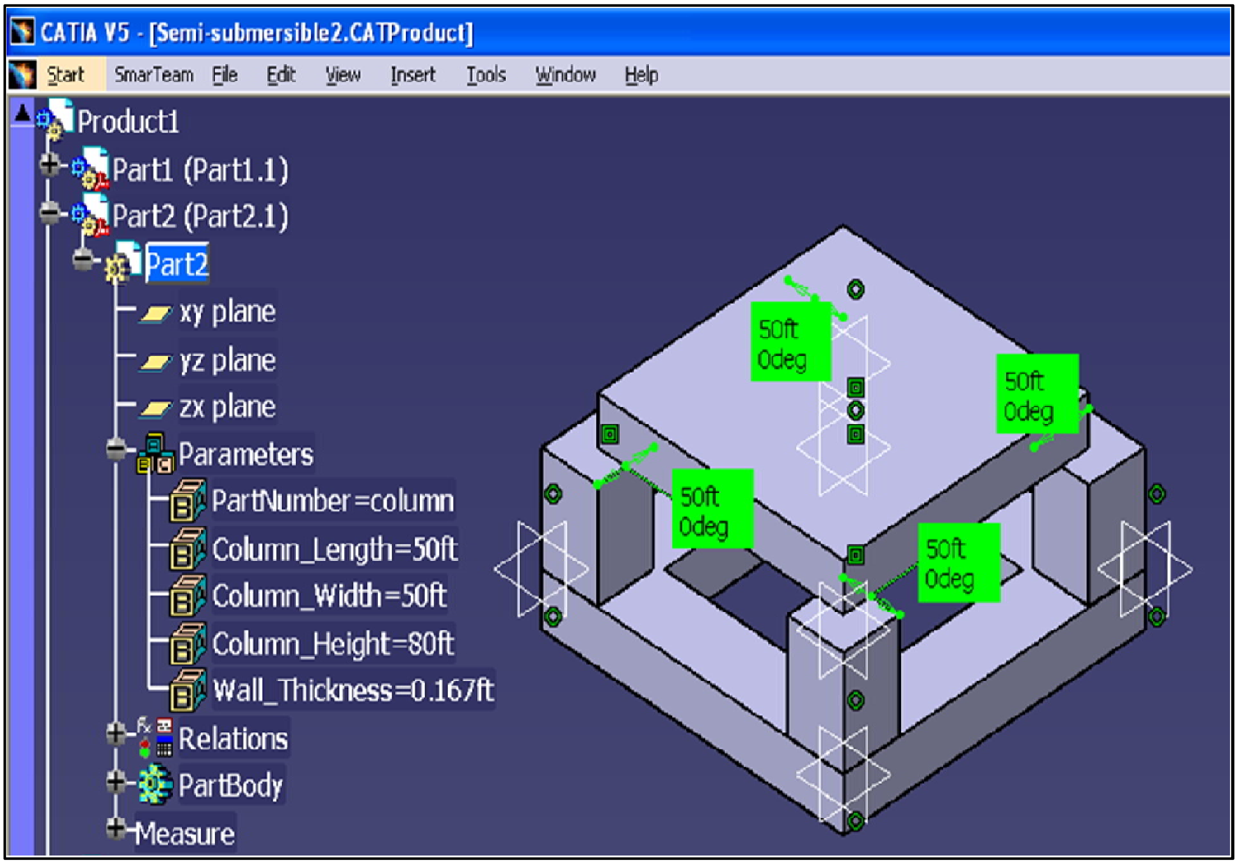

Figure 6: 50ft x 50ft Waterplane Area of Column CAD model

The other two models are for 50.5ft x 50.5ft (15.392m x 15.392m) and 52ft x 52ft (15.85m x 15.85m) waterplane area of column. The models are as shown below;

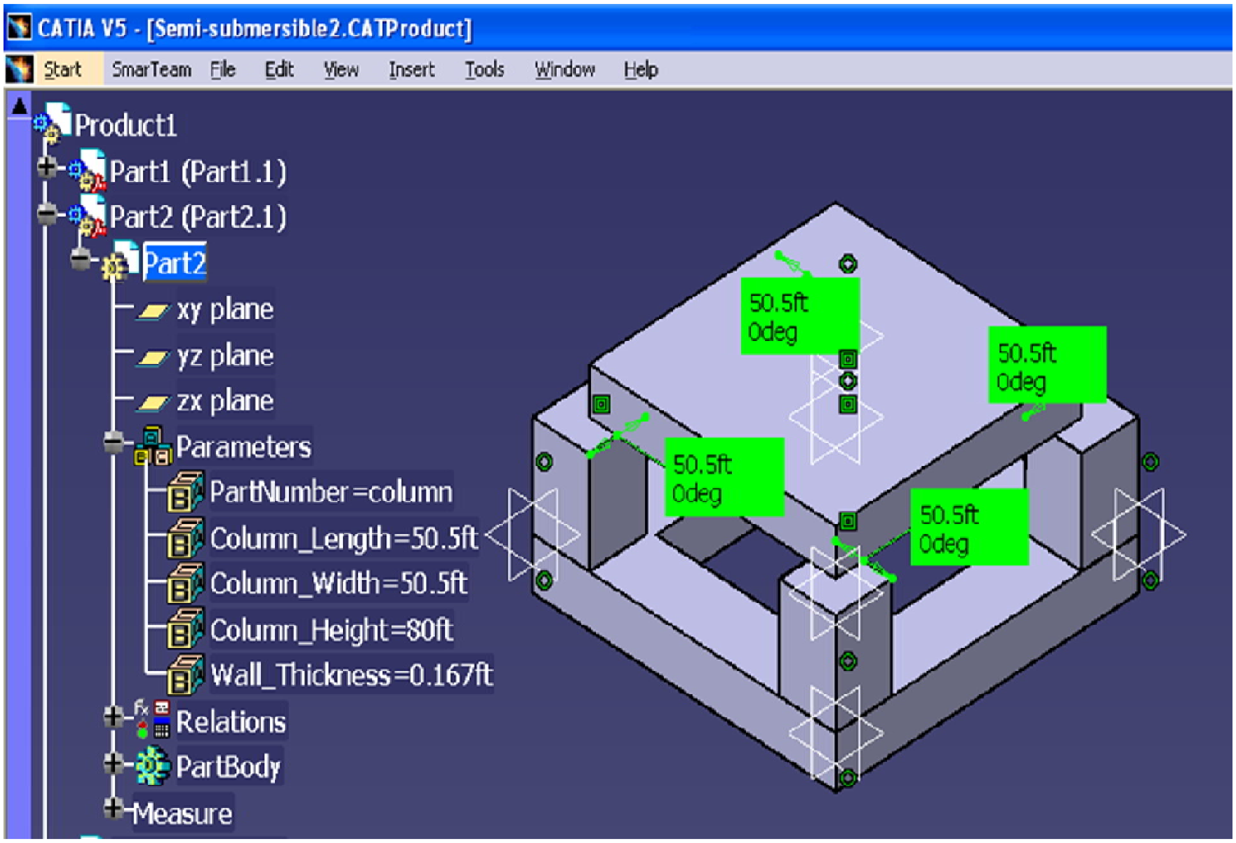

Figure 7: 50.5ft x 50.5ft Waterplane Area of Column CAD Model

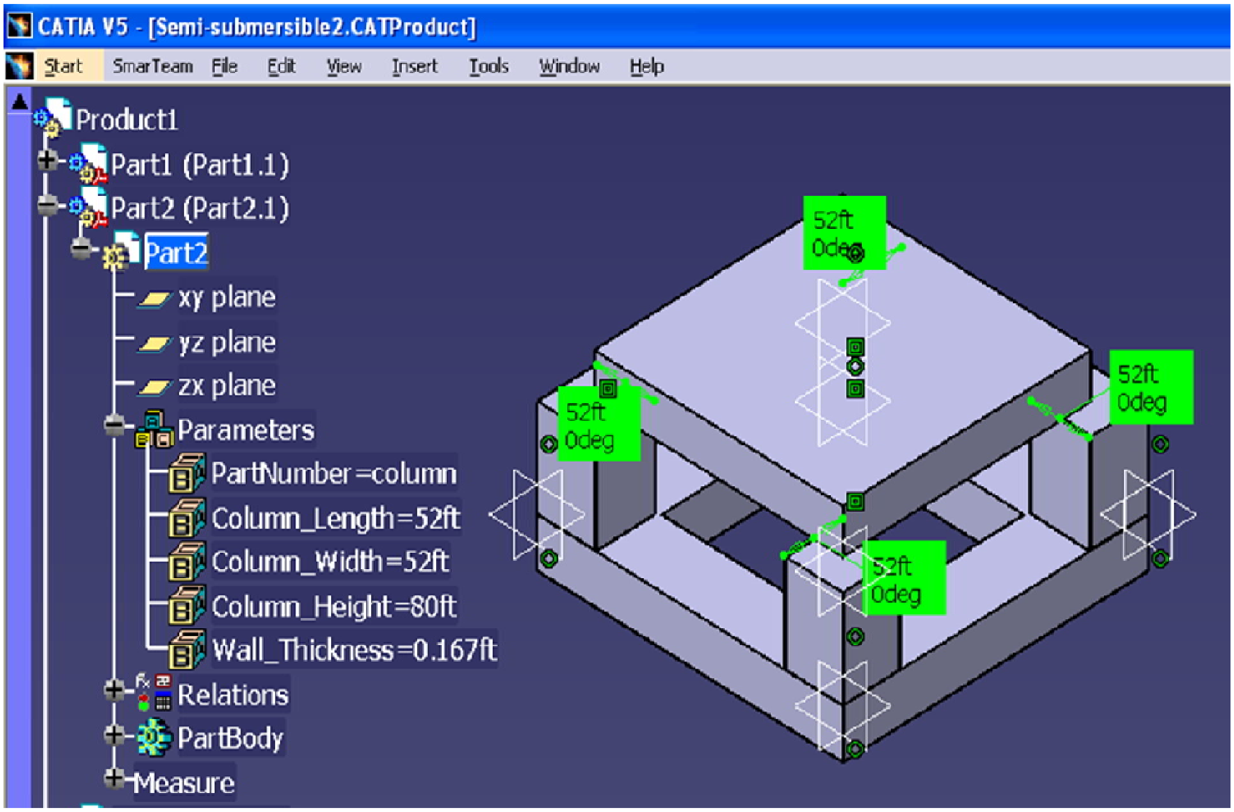

Figure 8: 52ft x 52ft Waterplane Area of Column CAD Model

Appendix B shows the steps in developing the semi-submersible CAD model based on part design module in CATIA V5R12.

The parameters and formula function is used to compute VCG and draft automatically. Figure 9 below shows the functions created with the model in CATIA V5R12.

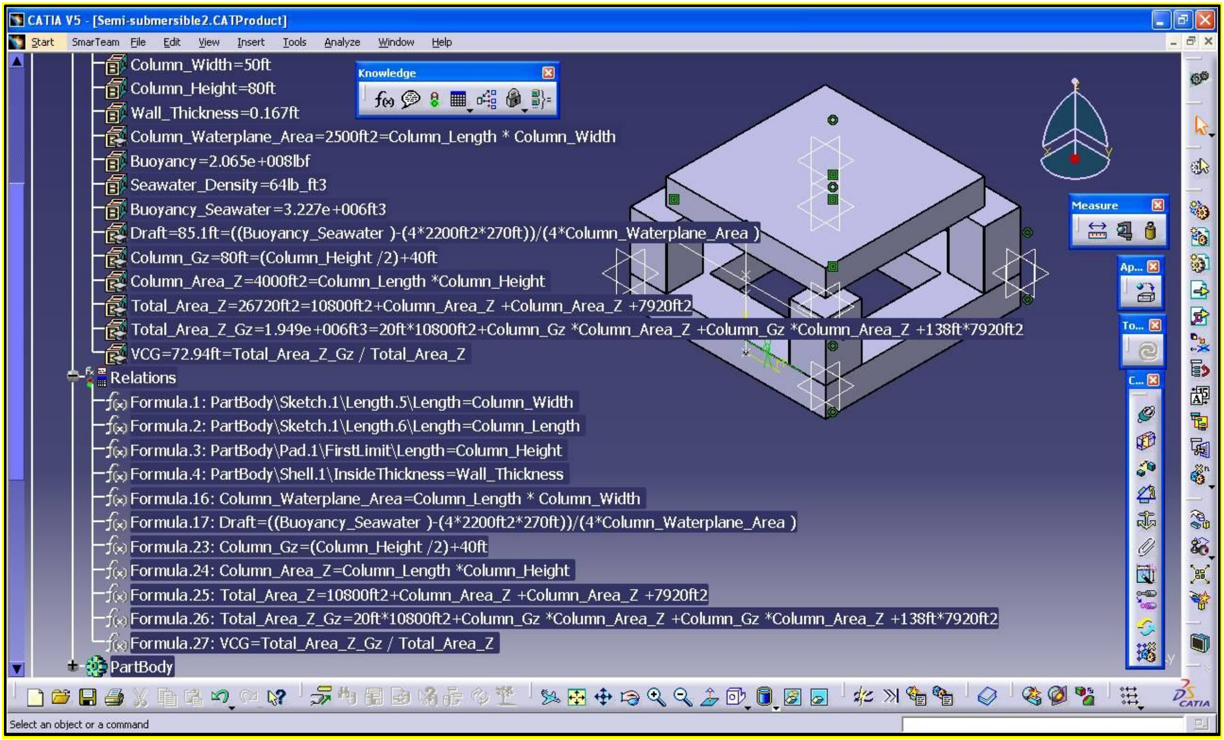

Figure 9: Parameters and Formula Function is used to compute VCG and Draft

By using the buoyancy formula and dimensions given in the literature, draft for the new waterplane area can be calculated as shown in the table below;

Table 3: Draft Values

Water plane area of column	**Draft**
50ft x 50ft	85ft
50.5ft x 50.5ft	83.33ft
52ft x 52ft	78.59ft

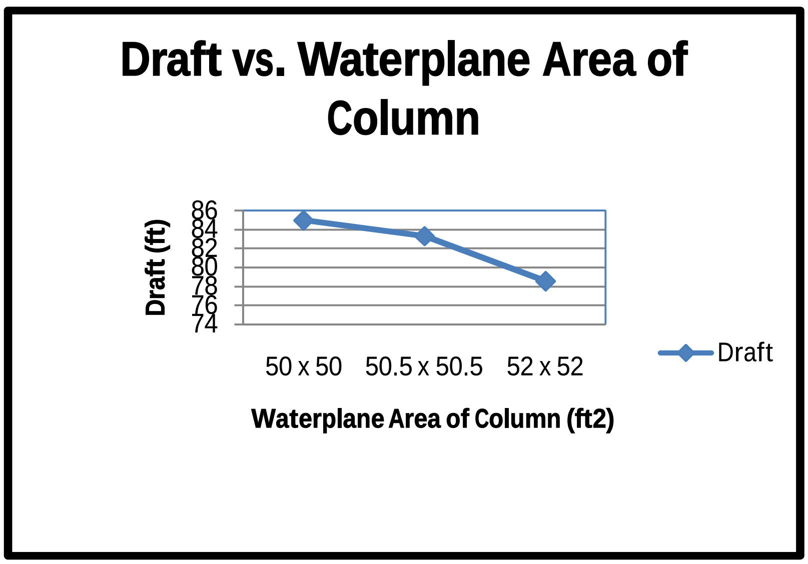

Figure 10: Draft against Waterplane Area of Column

By using the centroid formula, the semi-submersible's vertical center of gravity has been calculated and the values for the three sets of waterplane area of column are as below;

Table 4: Vertical of Center of Gravity Values

Water plane area of column	Vertical center of gravity
50ft x 50ft	72.94ft
50.5ft x 50.5ft	72.96ft
52ft x 52ft	73.02ft

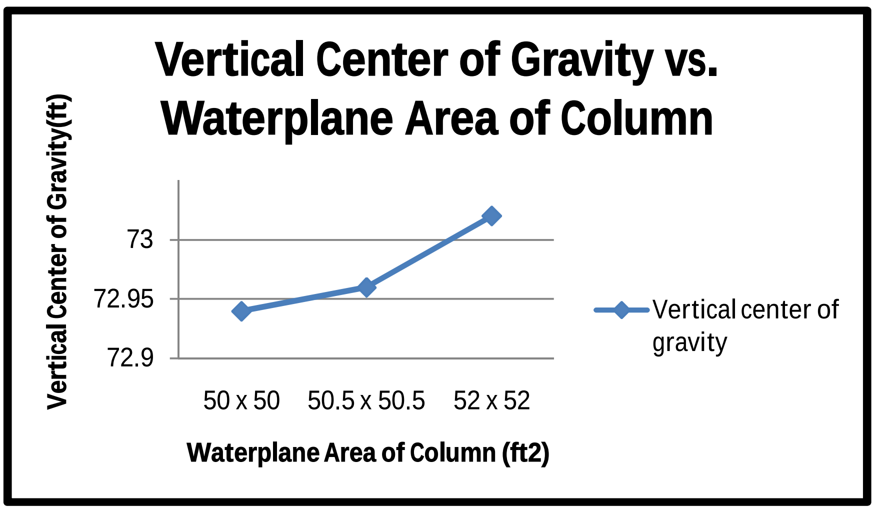

Figure 11: Vertical Center of Gravity against Waterplane Area of Column

Table 5 and Figure 12 below show the relation between VCG and draft.

Table 5: Vertical Center of Gravity and Draft Values

Vertical Center of Gravity (ft)	Draft (ft)
73.02	78.9
72.96	83.33
72.94	85

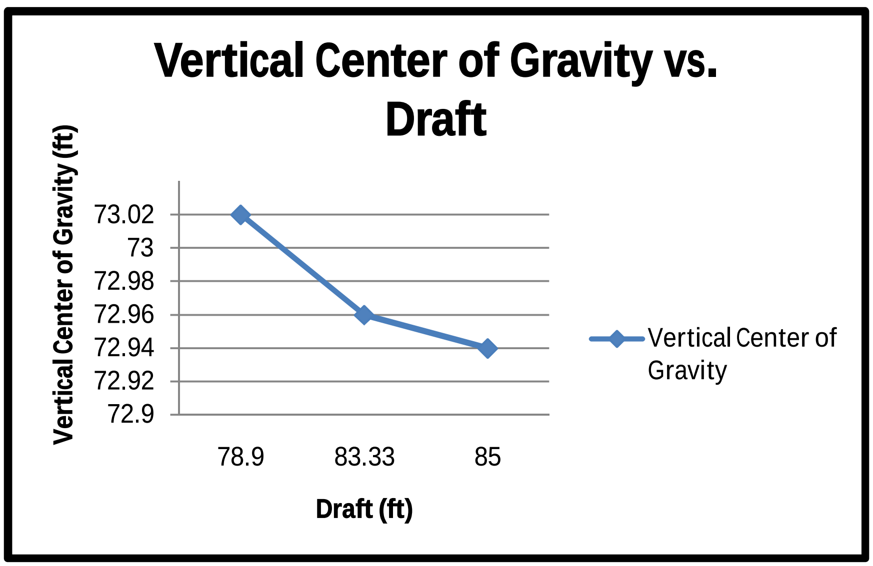

Figure 12: Vertical Center of Gravity against Draft

4.2 Discussion

Results show that three hull sections of semi-submersible CAD models were developed using CATIA V5R12. The CAD models were created from sketcher to part design and assembled in an assembly design module. The sequence of building the hull section from the pontoon, column and topsides are based on the connection of the parts from each other. The pontoon is the lowest part of the hull section and it is connected to the four columns. Topside is the upper part of the hull section and was combined at the end. The parts are developed concurrently with the formula function. This is because all the dimensions need to be named.

The parameters and formula function is used to specify the dimensions on the model to a specification tree and to insert formula which involves the specified dimensions. With this function, VCG and draft formula are calculated simultaneously when the specified dimension is changed. For example, when waterplane area of column is changed from 50ft x 50ft (15.24m x 15.24m) to 52ft x 52ft (15.85m x 15.85m), the draft’s value would also changed from 85ft (25.908m) to 78.9ft (24.049m).

The benefit of this idea is that it would give an instant value for engineers to review the dimensions chosen for the semi-submersible’s hull section and to proceed with next steps. This model also can be used for simulation or for easy understanding on the semi-submersible’s condition and effect by having it virtually on screen. The results can be a basic assumption or a prediction for the semi-submersible’s design calculation for wave, wind and current forces as well as the weight, strength and stress analysis.

Figure 10: Draft against Waterplane Area of Column shows that as the waterplane area of column increases, the draft will be reduced. This shows that increasing the waterplane area of column will reduce the semi-submersible's stability. The purpose of semi-submersible vessel is to minimize vessel motion due to wave action [21]. A deep-draft semi-submersible will minimize the exposed area of column from getting the impact of wave action thus stabilize the semi-submersible. For operating condition, the draft values would be in the range of 80-100ft meanwhile for severe storm or survival condition, the draft values can be from 50 to 60ft.

Every three-dimensional object has three centers of gravity, one for each dimensional plane. There is a horizontal center of gravity (HCG), a lateral center of gravity (LCG) and a vertical center of gravity (VCG). VCG is normally expressed as being "x" number of inches above level ground. This is the midpoint of the vertical distribution of the weight of the unit. VCG has a direct correlation to floaters rollover stability where the higher the VCG, the higher the rollover propensity.

Figure 11: Vertical Center of Gravity against Waterplane Area of Column shows that the increment of waterplane area of column increased the VCG therefore, tendency for the semi-submersible to roll or topple increases as well. Manual calculation on the VCG was conducted to compare with the values computed in CATIA V5R12. The calculation can be seen in Appendix C.

Figure 12: Vertical Center of Gravity against Draft shows the relation between VCG and draft. When the draft value increases, the VCG will decrease. For this study, the maximum value of draft is 85ft (25.908m) and the minimum value of VCG is 72.94ft (22.232m). If the model's dimensions go beyond this constraint, the semi-submersible will be flooded.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Referring to the objectives, the three CAD models of four-column ring pontoon semi-submersible's hull and the analysis are the initiator for the offshore floaters design library which eliminates some iteration in conceptual design stage for future design selection work.

The increment of waterplane area of column increases the vertical center of gravity and reduces the draft. Both conditions increased the probability of the semi-submersible to be flooded.

As mentioned in the problem statement, the unavailability of design library of offshore floaters in PETRONAS causes an extensive iterative process in concept design and selection stage. Therefore, the success of this project is an opening for PETRONAS to further improve its selection approach in meeting specific requirements or criterion. The VCG and draft values obtained increases the decision reliability and narrow down the floaters dimension scope. The model library also is user friendly and time-saver. However, the models is focused for one type of semi-submersible which is the four-column ring pontoon model with no effect from environmental condition and need access to CATIA V5R12 software or the latest version.

5.2 Recommendation

It is recommended that further enhancement on the library should be made. One of the proposals is to develop the six-column and eight-column twin pontoon semi-submersible's hull model to meet the industries' requirement.

Besides that, other parameters to analyze stability which can be inserted in the CAD model library are;

- Metacentric height
- Angle of heel
- Restoring moment
- Righting arm

Further study also can be made towards the effect of topsides weight and widen the scope of dimensions.

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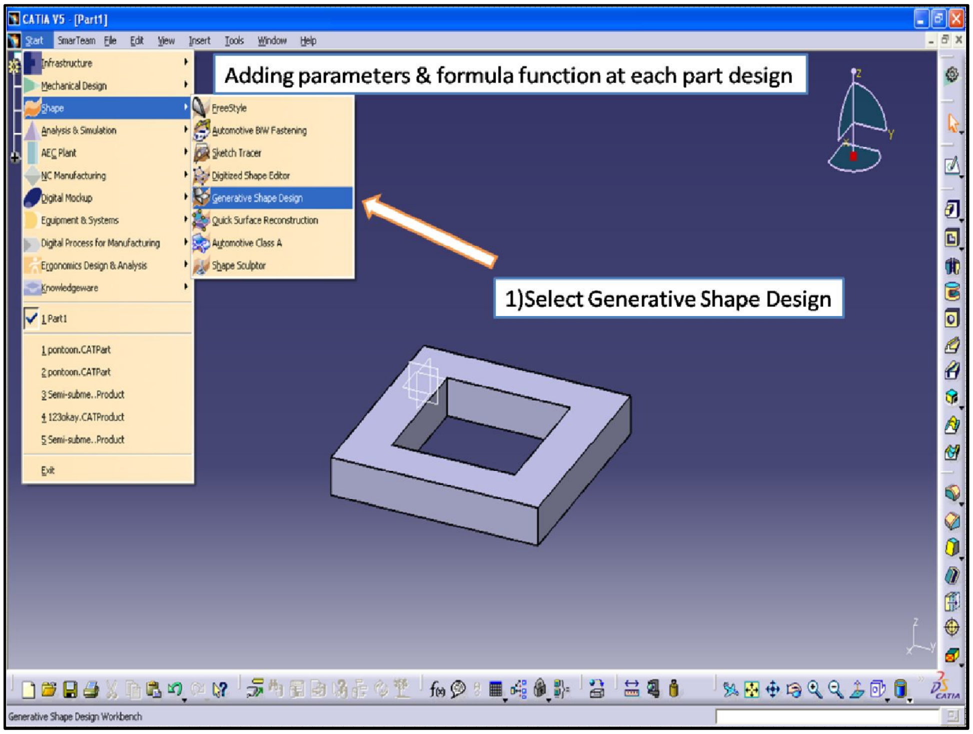
STEPS IN DEVELOPING THE FORMULA FUNCTION



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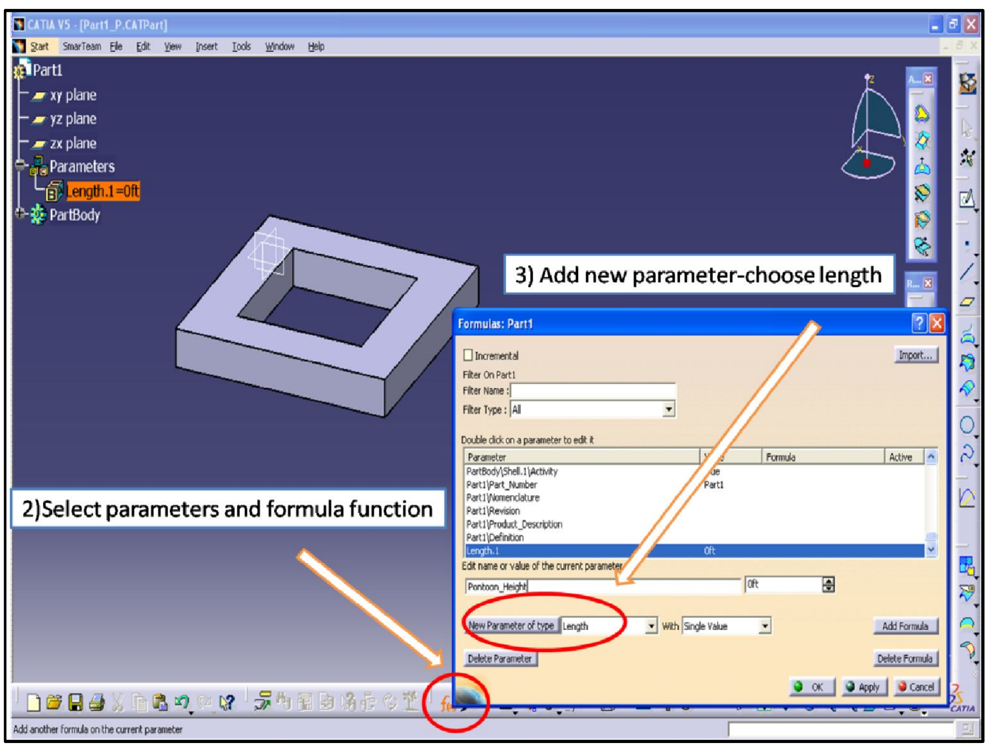

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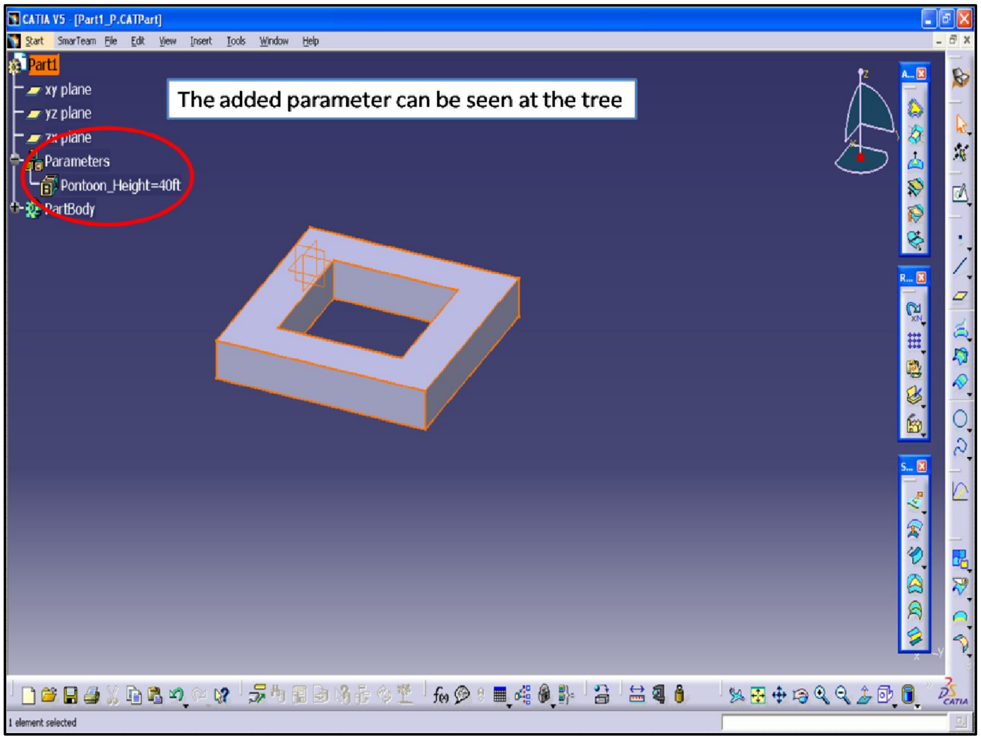

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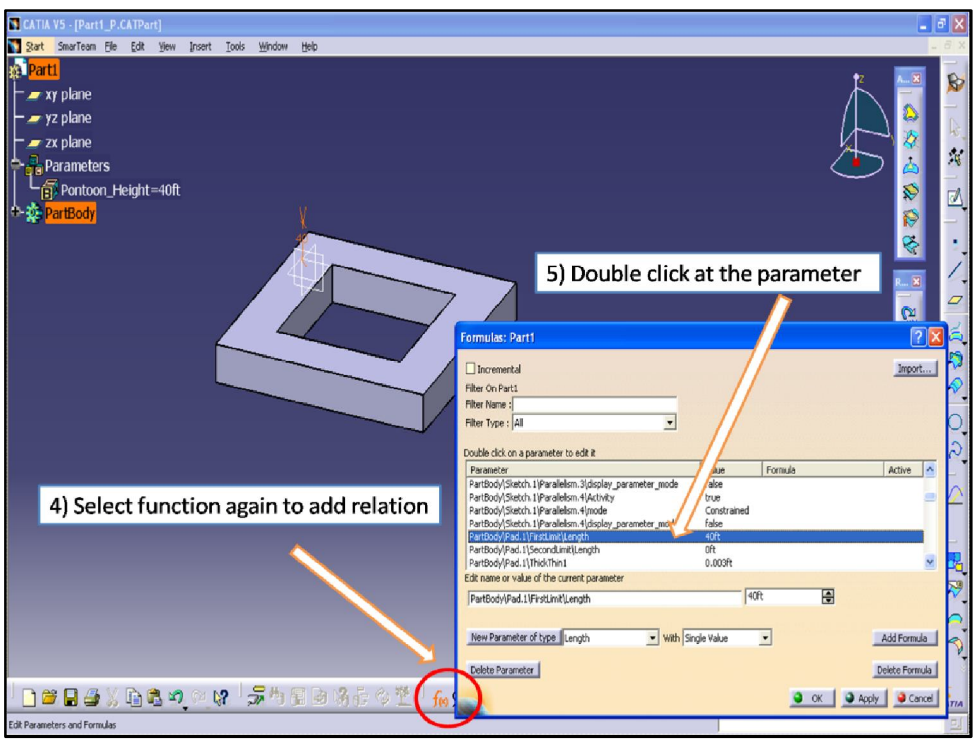
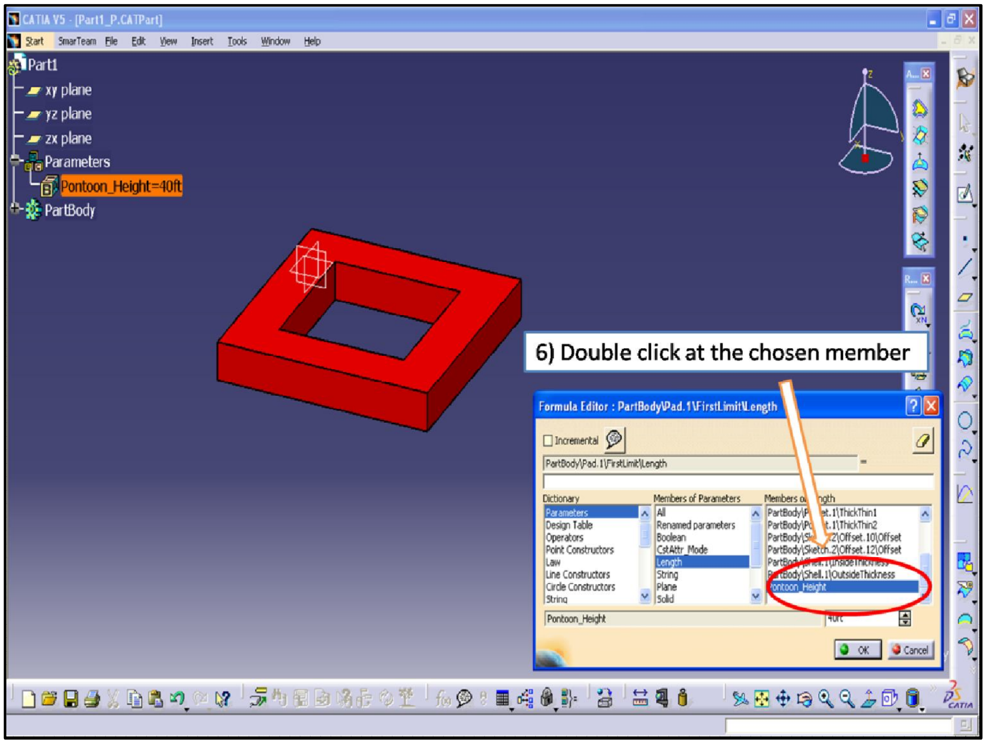


A4: Step 4



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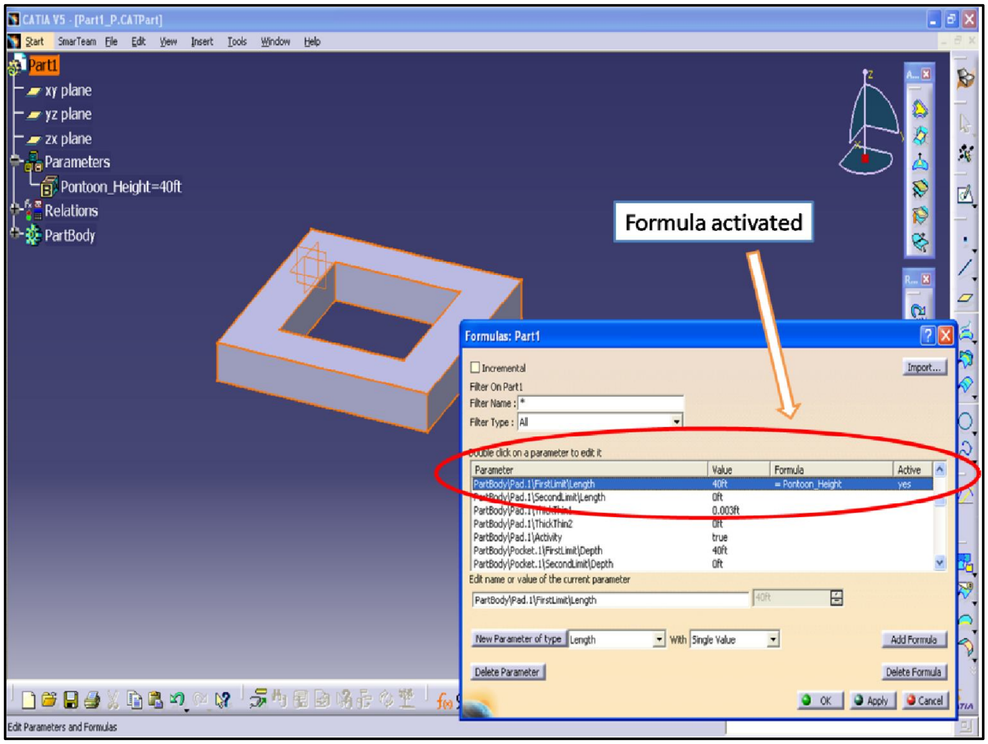

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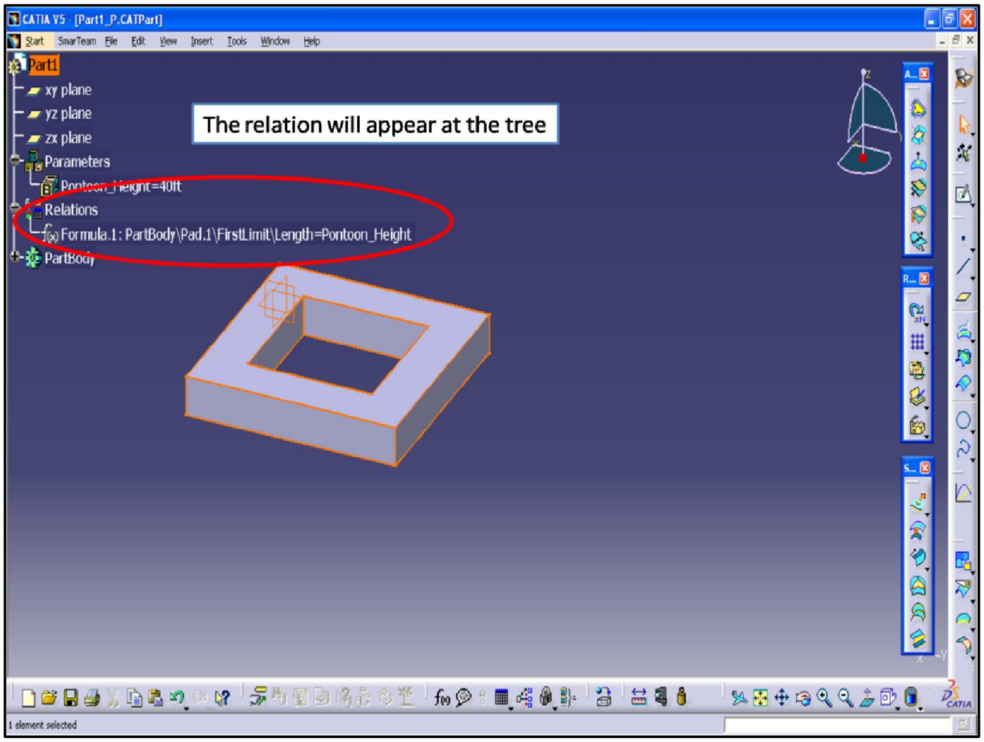
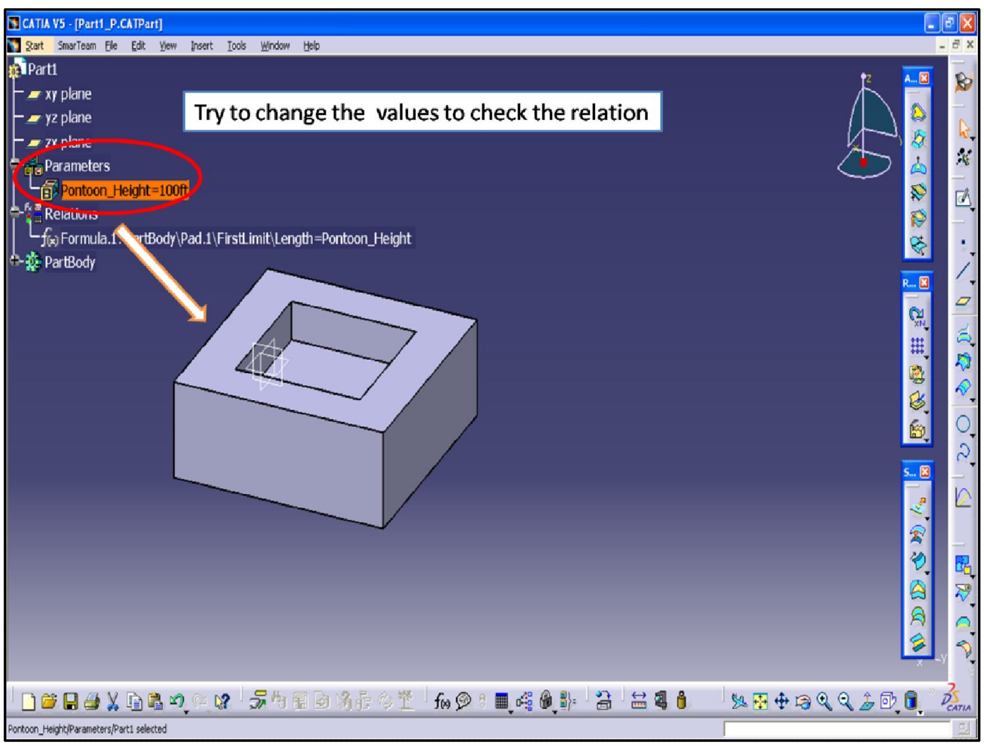
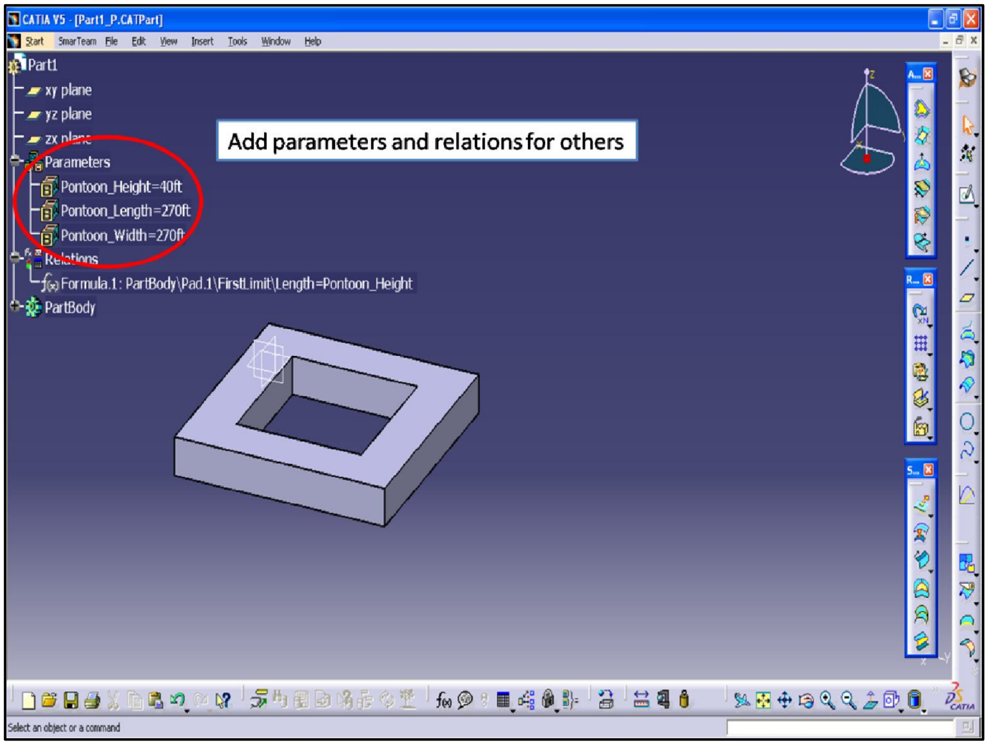


A7: Step 7

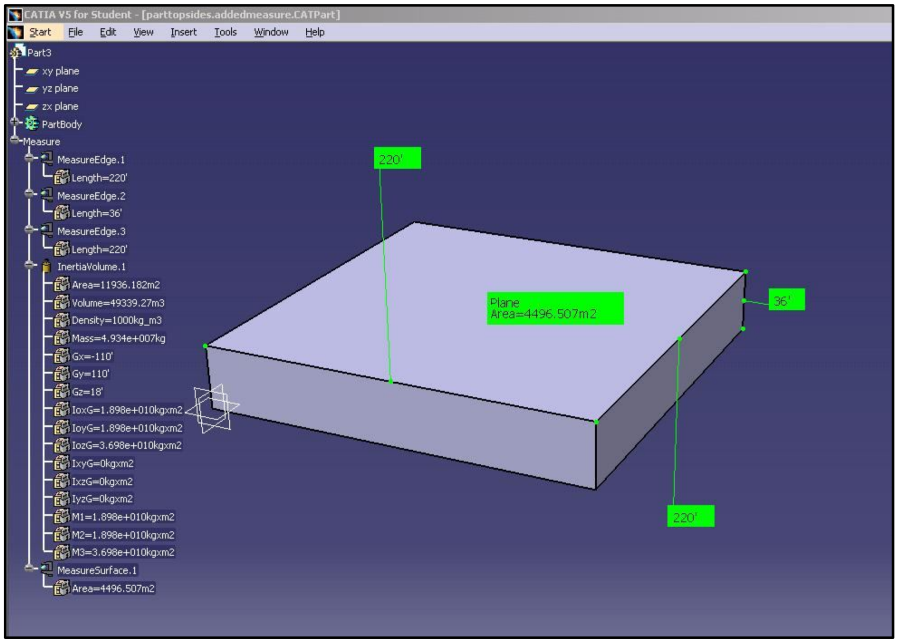


A8: Step 8

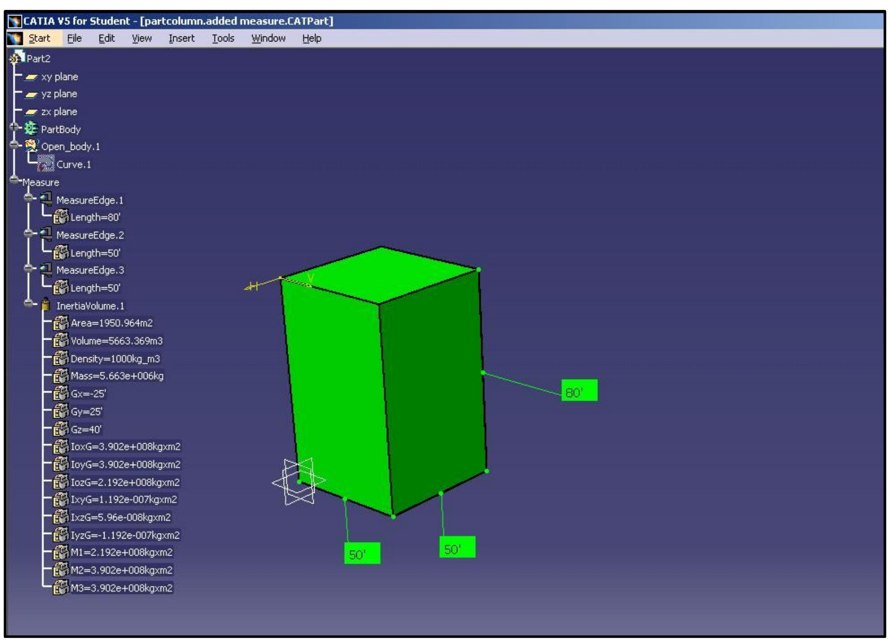

CATIA V5 - [Part1_P.CATPart]
Start SmarTeam File Edit View Insert Tools Window Help
Part1
xy plane
yz plane
zx plane
Parameters
Pontoon_Height=40ft
Pontoon_Length=270ft
Pontoon_Width=270ft
Relations
Formula.1 : PartBody\Pad.1\FirstLimit\Length=Pontoon_Height
PartBody
Add parameters and relations for others
Select an object or a command

A9: Step 9

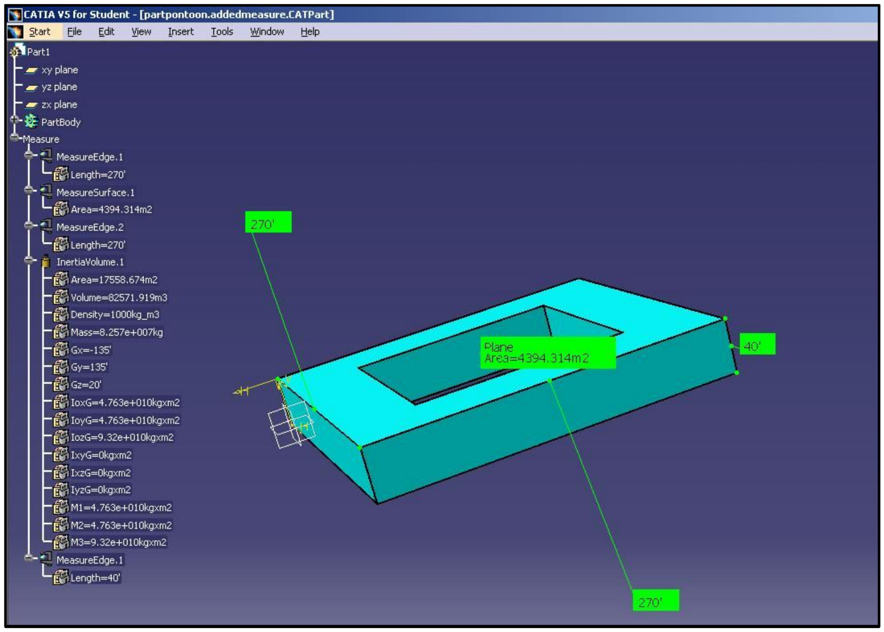
STEPS IN DEVELOPING THE SEMI-SUBMERSIBLE CAD MODEL



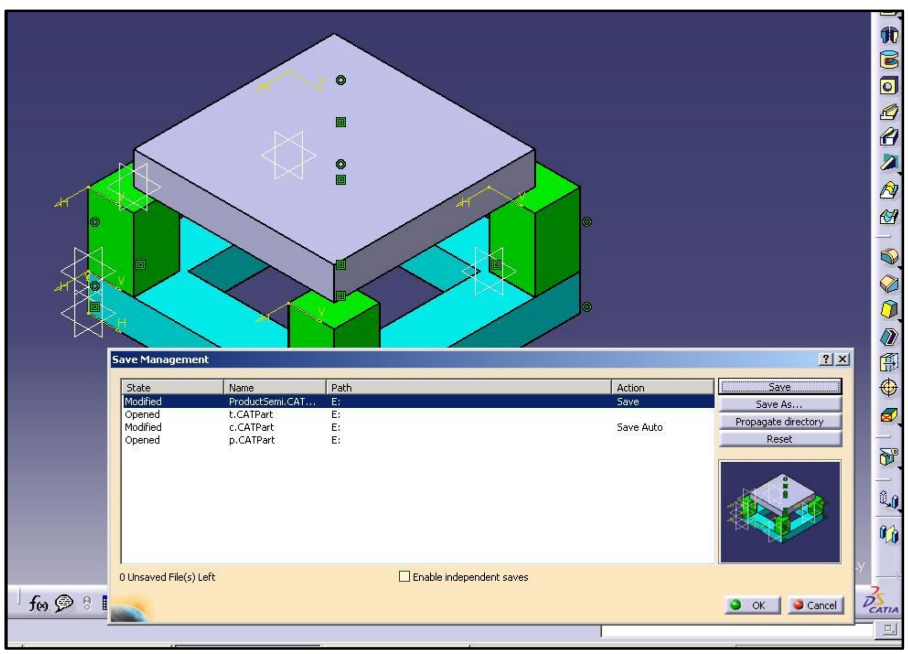
B1: Topsides Part Design



B2: Column Part Design



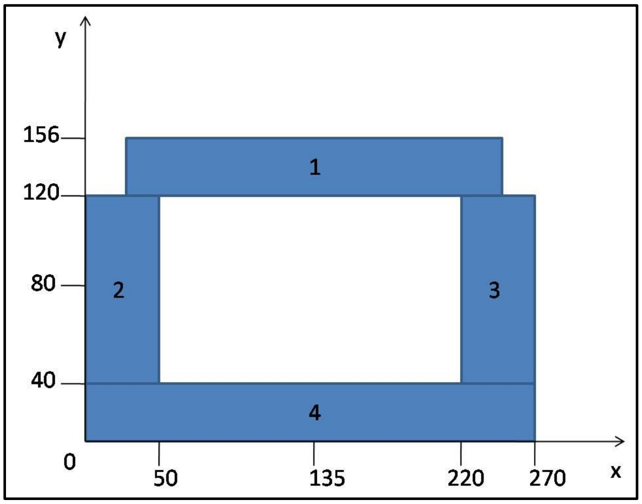
B3: Pontoon Part Design



B4: Save Management Function in Assembly Design

VCG AND DRAFT CALCULATION

Waterplane Area of Column = 50 x 50 ft



B1: Centroid Diagram for 50 x 50ft

Area 1 = 220 x 36 = 7920
Area 2 = 80 x 50 = 4000
Area 3 = 80 x 50 = 4000
Area 4 = 270 x 40 = 10800

Total Area = 26720

$$\bar{x} = \frac{x_1 * A_1 + x_2 * A_2 + x_3 * A_3 + x_4 * A_4}{A_1 + A_2 + A_3 + A_4}$$

$$\bar{y} = \frac{y_1 * A_1 + y_2 * A_2 + y_3 * A_3 + y_4 * A_4}{A_1 + A_2 + A_3 + A_4}$$

Centroid: ($\bar{x}$, $\bar{y}$)

$\bar{y}$ = Vertical Center of Gravity

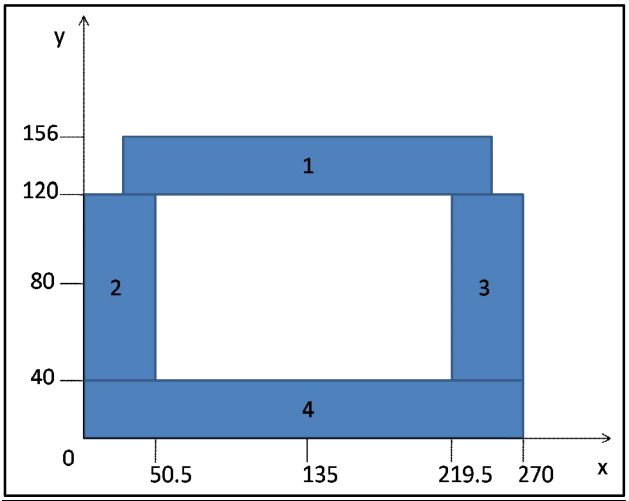
$$\bar{x} = \frac{135 \times 7920 + 25 \times 4000 + 245 \times 4000 + 135 \times 10800}{26720}$$

$$\bar{x} = 135$$

$$\bar{y} = \frac{138 \times 7920 + 80 \times 4000 + 80 \times 4000 + 20 \times 10800}{26720}$$

$$\bar{y} = 72.94$$

Waterplane Area of Column = 50.5 x 50.5 ft



B2: Centroid Diagram for 50.5 x 50.5ft

Area 1 = 220 x 36 = 7920
Area 2 = 80 x 50.5 = 4040
Area 3 = 80 x 50.5 = 4040
Area 4 = 270 x 40 = 10800

Total Area = 26800

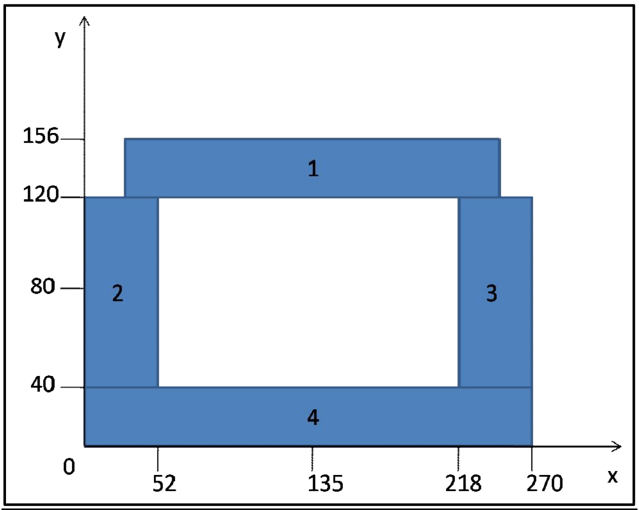
$$\bar{x} = \frac{135 \times 7920 + 25.25 \times 4040 + 244.75 \times 4040 + 135 \times 10800}{26800}$$

$$\bar{x} = 135$$

$$\bar{y} = \frac{138 \times 7920 + 80 \times 4040 + 80 \times 4040 + 20 \times 10800}{26800}$$

$$\bar{y} = 72.96$$

Waterplane Area of Column = 52 x 52 ft



B3: Centroid Diagram for 52 x 52ft

Area 1 = 220 x 36 = 7920
Area 2 = 80 x 50.5 = 4160
Area 3 = 80 x 50.5 = 4160
Area 4 = 270 x 40 = 10800

Total Area = 27040

$$\bar{x} = \frac{135 \times 7920 + 26 \times 4160 + 244 \times 4160 + 135 \times 10800}{27040}$$

$$\bar{x} = 135$$

$$\bar{y} = \frac{138 \times 7920 + 80 \times 4160 + 80 \times 4160 + 20 \times 10800}{27040}$$

$$\bar{y} = 73.02$$

Draft Calculation

$$Buoyancy = [(4 \times waterplane\ area\ of\ column \times draft) + (4 \times cross\ sectional\ area\ of\ pontoon \times length\ of\ pontoon)] \times seawater\ density$$

Seawater density = 64 lb/ft^3

Length of pontoon = 270ft

Cross sectional area of pontoon = 55 x 40 ft =2200ft^2

When waterplane area of column = 50 x 50ft =2500 ft^2 and Draft = 85ft

$$Buoyancy = [(4 \times 250 \times 85) + (4 \times 220 \times 270)] \times 64$$

$$Buoyancy = 206.464\, exp06\ lb$$

Setting the buoyancy value as constant and making draft as the unknown value.

When waterplane area of column = 50.5 x 50.5 ft = 2550.25ft^2

$$206.464exp06 = [(4 \times 2550.25 \times draft1) + (4 \times 2200 \times 270)] \times 64$$

$$draft1 = 83.33ft$$

When waterplane area of column = 52 x 52 ft = 2704ft^2

$$206.464exp06 = [(4 \times 2704 \times draft2) + (4 \times 2200 \times 270)] \times 64$$

$$draft2 = 78.59ft$$